Structure Design Process

Hydrology
↓
Site Assessment
↓
Alignment and Profile
↓
Bed and Banks
↓
Structure
↓
Sediment Mobility & Stability

Structure design steps

• Choose a structure width based on:
  – Bankfull width
  – Minimum bank width
  – Floodplain requirements
  – Other passage requirements

• Add LVAP & road surface to:
  – Cross-section graph
  – Profile graph

• Select an initial structure:
  – Type and size
  – Id min & max cover requirements
Structure design steps

- Select an elevation for the invert or bottom of footer
- Verify cover requirements & embedment depth
- Determine structure length taking into account:
  - side-slope
  - end treatments
- Check
  - hydraulic capacity (HW/D<0.8 for Q_{100})
  - bed mobility
  - key piece stability
- Repeat as needed

Structure type and size

The structure must wrap around a design channel that is bankfull width, has stable banks and is capable of handling vertical adjustments, flood flows, debris, sediment transport and floodplain conveyance!
Culvert size & type factors based on project objectives

- Bankfull width minimum
- Capacity for the Q_{100} with HW/D<0.8 plus debris
- Self-sustaining bed with stable key pieces
- Minimize maintenance needs
- Passage of non-aquatic species
- Maintain floodplain processes

Culvert size & type factors based on site conditions and engineering constraints

- Alignment of channel to road
- Ice plugging in severe cold climate
- Large bed material relative to culvert width
- High water level stage during floods
- Soft foundations or shallow bedrock
- High conveyance across flood plain
- Height of road and load requirements
- Access for equipment and materials
- Utilities
Stream simulation culvert width

Benefits of structures **wider** than bankfull width:

- Banks match reference channel
- Minimize inlet contraction during high flow events
- Can create dry habitat conditions for passage of additional organisms—increases “openness”
- More important on high volume traffic roads

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Is wider always better?

**Very low gradient stream simulation design**

- Maybe not - in sand bed streams with low flows
- Without structure to create banks or a thalweg
- Sand spreads out to create a flat, uniform bed
- Shallow water may impede passage of some sp.

Example of an open-bottom arch in Michigan.
Stream Crossing Design and Exercises: Part 2

7-Structure design

April 2016

Road-Stream Crossings Workshop
Platteville, WI
Stream simulation culvert width

- First estimate: Span BF channel and banks

Structure types

- Bridge
- Box
- Bottomless Arch
- Pipe Arch
- Embedded Round
Pipes

- Max embedment = max pipe width
- Embedment depth can be a limitation
- Up to 37’ wide (horizontal ellipse)

Box Culverts

- Short & wide
- Embedment depth varies, designer has a choice

Culvert size and elevation

- Round Pipe
  - Diameter, D or rise
  - 80% D for Q_{100}
  - 50% Dia. maximum
- Bottomless Pipe
  - Project profile bed elevation
  - Per site assessment, scour analysis and foundation design
  - Lower VAP line
  - LVAP = max residual pool depth x 1-2 depending on bed material size
- Range of possible bed surface elevation from long profile analysis
Structure size and shape is an integration of the project objectives, site conditions and engineering constraints.

- **Round Pipe**
- **Bottomless Pipe**

Use of the larger round CMP would require increase in road elevation.

Range of possible bed surface elevation from long profile analysis.

50% D maximum.

Structure examples:

- 12’ wide ellipse
- 25’ wide alum box
- 24’ wide conc arch
- 12’ wide pipe-arch
- 30’ wide bridge
- 20’ wide conc box
Floodplain considerations
flood conveyance

a. Confined
b. Unconfined
   with wider culvert
c. Unconfined
   with floodplain culverts

Design the channel and floodplain
Design the culvert to fit

Culvert Width

Road Fill
Road Dip

Floodplain culvert in flood swale
Reference channel
bankfull cross section

Floodplain
Floodplain considerations
animal passage

Allow passage of large mammals

Very low gradient stream simulation design
Torpee Cr at Hwy 32

Structure elevation and length
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• Repeat as needed
Stream simulation structure shape and size exercise

Hydraulic modeling for existing structure

Existing 9.5' Circular CMP
Unt Rountree at W Main St
Hydraulic modeling for existing and proposed structure

Cross-section 6 located 33 ft upstream from culvert inlet

Existing 9.5’ Circular CMP
Unt Rountree at W Main St

Proposed 20’ Arch
Unt Rountree at W Main St

Hydraulic modelling for proposed structure

Proposed 20’x8’ Arch Unnamed Tributary to Rountree at W Main St
Questions?

Credits: Gary Larson, The Far Side